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[Designation of Document] SPECIFICATION

[Title of the Invention] HEAD DRIVE APPARATUS AND METHOD FOR INKJET PRINTER

[Claims]

[Claim 1] In a head drive apparatus, for an inkjet printer, in which a piezoelectric element provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a head drive circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus for an inkjet printer is characterized by comprising

a first capacitor for applying a predetermined bias voltage to a ground-side electrode of each piezoelectric element and a charge circuit for charging said first capacitor utilizing electric charge obtained by discharging each piezoelectric element.

[Claim 2] A head drive apparatus for an inkjet printer according to claim 1, characterized in that said charge circuit includes a second capacitor that is charged using electric charge obtained by discharging each piezoelectric element.

[Claim 3] A head drive apparatus for an inkjet printer according to claim 2, characterized in that said charge circuit includes a constant voltage circuit for stabilizing the charge voltage of the second capacitor and applying the stabilized charge voltage to the first capacitor.

[Claim 4] A head drive apparatus for an inkjet printer according to claim 2 or 3, characterized in that the second capacitor of said charge circuit is gradually charged before print start.

[Claim 5] In a head drive method, for an inkjet printer, in which a piezoelectric element provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a head drive circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive method for an inkjet printer is characterized in that

a first capacitor connected to a ground-side electrode of each piezoelectric element is charged by a charge circuit utilizing electric charge obtained by discharging each piezoelectric element, thus applying a predetermined bias voltage to the ground-side electrode of each piezoelectric element.

[Claim 6] A head drive method for an inkjet printer according to claim 5, characterized in that said charge circuit includes a second capacitor that is charged using electric charge obtained by discharging each piezoelectric element.

[Claim 7] A head drive method for an inkjet printer according to claim 6, characterized in that said charge circuit includes a constant voltage circuit for stabilizing the charge voltage of the second capacitor and applying the stabilized charge voltage to the first capacitor.

[Claim 8] A head drive method for an inkjet printer according to claim 6 or 7, characterized in that the second capacitor of said charge circuit is gradually charged before print start.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention Belongs]

The present invention relates to a head drive technique, for an inkjet printer, configured such that the ground side of piezoelectric elements provided to correspond to nozzles for ejecting ink droplets is held at an intermediate potential.

[0002]

[Prior Art]

Conventionally, an inkjet color printer of the type in which inks of several colors are ejected from a printhead has prevailed as an output apparatus of a computer and has been widely used to print an image processed by the computer or the like in multiple colors and tones.

[0003]

For example, an inkjet printer using a piezoelectric element as a drive element for ejecting ink is configured as follows. Plural piezoelectric elements provided to correspond to plural nozzles of a printhead are selectively driven. Thereby, ink droplets are ejected through the nozzles based on the dynamic pressure of the individual piezoelectric elements and adhered to print paper. Thereby, dots are formed on the print paper, thus performing printing.

[0004]

Here, each piezoelectric element, provided to correspond to each nozzle for ejecting an ink droplet, is driven based on a drive signal supplied from a driver IC (head drive circuit) mounted in a printer body or the printhead, thus ejecting an ink droplet.

[0005]

In the meantime, in such a piezoelectric element, during non-drive (i.e. when printing is not performed), electric charge stored by charging is

discharged due to insulation resistance and the voltage of the piezoelectric element is lowered, thereby affecting the ink ejection in some cases.

[0006]

Consequently, Japanese Patent No. 3097155 obtained by the present inventor discloses a head drive apparatus and method configured such that a charge voltage is applied to the piezoelectric element with a different timing from the drive timing, thus maintaining the charge voltage.

[0007]

[Problems that the Invention is to Solve]

However, in such head drive for the inkjet printer, the drive signal applied to each piezoelectric element is configured, for example, such as to be set to a high voltage during non-drive and have the voltage lowered during drive. In this case, power consumption becomes large and the voltage applied to the piezoelectric element becomes comparatively high. Therefore, a voltage drop due to the aforesaid discharging is also large, so that a power loss is large.

[0008]

Besides, when an increase in density of print dots is intended to be realized for an improvement in print quality, the gap between the electrodes of the piezoelectric elements adjacent to each other is narrowed. However, in case where the driven piezoelectric element and the non-driven piezoelectric element are adjacent to each other, when the voltage between the electrodes of these piezoelectric elements rises, in some cases, discharge occurs between the electrodes of these piezoelectric elements.

[0009]

Furthermore, each piezoelectric element is reduced in size due to the increase in density and thus reduced in withstanding pressure. Therefore, when the increase in density further proceeds, the maximum voltage of the drive signal exceeds the withstanding pressure of the piezoelectric element. Thus, there is the possibility that the piezoelectric element will not operate normally. Consequently, insulating such as filling of an insulation material will be needed between the electrodes of the piezoelectric elements.

[0010]

On the contrary, there is also a head drive method such that the ground side of each piezoelectric element is held at the intermediate potential of the drive signal. According to such a head drive method, it is possible to prevent the discharge between the electrodes of the piezoelectric elements that occurs upon the aforesaid increase in density. However, in correspondence to variation in the drive signal, the voltage need be varied, and charging and discharging need be switched, so that a bi-directional variable power supply will be needed.

[0011]

Consequently, an object of the invention is to provide a head drive apparatus and method, for an inkjet printer, configured such that a voltage applied between the electrodes of each piezoelectric element is lowered with a simple configuration.

[0012]

[Means for Solving the Problems]

To solve the aforesaid problems, in the invention, a bias voltage from a first capacitor charged by a charge circuit is applied to a ground-side

electrode of each piezoelectric element, thus holding the ground side of each piezoelectric element at a higher potential than a ground potential.

[0013]

That is, in the head drive apparatus for an inkjet printer of claim 1, in which a piezoelectric element provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a head drive circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus for an inkjet printer is characterized by comprising a first capacitor for applying a predetermined bias voltage to a ground-side electrode of each piezoelectric element and a charge circuit for charging the aforesaid first capacitor utilizing electric charge obtained by discharging each piezoelectric element.

[0014]

Besides, in the head drive method for an inkjet printer of claim 5, in which a piezoelectric element provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal from a head drive circuit, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive method for an inkjet printer is characterized in that a first capacitor connected to a ground-side electrode of each piezoelectric element is charged by a charge circuit utilizing electric charge obtained by discharging each piezoelectric element, thus applying a predetermined bias voltage to the ground-side electrode of each piezoelectric element.

[0015]

According to this configuration, based on the charge voltage of the

first capacitor charged by the charge circuit utilizing the discharged electric charge of the piezoelectric element, the bias voltage is applied to the ground-side electrode of the piezoelectric element. Thereby, the ground-side electrode of the piezoelectric element is held at the bias voltage. Accordingly, the electric charge that has been discarded from the piezoelectric element during discharging is utilized as power supply. Thereby, power consumption is reduced and a voltage drop due to natural discharge of the piezoelectric element is small, so that a high-precision waveform can be realized.

[0016]

Furthermore, when the bias voltage is changed, the circuit constant of the charge circuit is properly changed to thereby enable an easy change of the bias voltage. Therefore, there is no need to newly design the charge circuit or replace the charge circuit with another one, thus enabling an easy accommodation.

[0017]

The head drive apparatus of claim 2 is characterized in that the aforesaid charge circuit includes a second capacitor that is charged using electric charge obtained by discharging each piezoelectric element. The head drive method of claim 6 is characterized in that the aforesaid charge circuit includes a second capacitor that is charged using electric charge obtained by discharging each piezoelectric element.

[0018]

According to this configuration, the first capacitor connected to the ground-side electrode of the piezoelectric element is charged via the second capacitor of the charge circuit. Thereby, the first capacitor applies the stable

bias voltage to the ground-side electrode of the piezoelectric element.

[0019]

The head drive apparatus of claim 3 is characterized in that the aforesaid charge circuit includes a constant voltage circuit for stabilizing the charge voltage of the second capacitor and applying the stabilized charge voltage to the first capacitor. The head drive method of claim 7 is characterized in that the aforesaid charge circuit includes a constant voltage circuit for stabilizing the charge voltage of the second capacitor and applying the stabilized charge voltage to the first capacitor.

[0020]

According to this configuration, the second capacitor of the charge circuit applies the charge voltage, via the constant voltage circuit, to the first capacitor connected to the ground-side of the piezoelectric element, thereby suppressing the variation in the charge voltage of the first capacitor. Accordingly, the bias voltage applied to the ground-side electrode of the piezoelectric element is held more constant.

[0021]

The head drive apparatus of claim 4 is characterized in that the second capacitor of the aforesaid charge circuit is gradually charged before print start. The head drive method of claim 8 is characterized in that the second capacitor of the aforesaid charge circuit is gradually charged before print start.

[0022]

According to this configuration, the second capacitor is gradually charged before print start, thereby gradually raising the output voltage of the

second capacitor and the charge voltage of the first capacitor. Therefore, the bias voltage applied to the ground-side electrode of each piezoelectric element by the first capacitor is also gradually raised. Accordingly, each piezoelectric element is prevented from malfunctioning due to a rise in bias voltage that occurs before print start.

[0023]

[Mode for Carrying out the Invention]

A head drive apparatus according to embodiments of the invention will be described with reference to the drawings. Additionally, since the embodiments to be described below are preferred embodiments of the invention, various technically preferable limitations are put thereon. However, the scope of the invention is not limited to these embodiments unless the following description specifically states any limitation on the invention.

[0024]

Fig. 1 shows the configuration of an embodiment of the head drive apparatus according to the invention. In Fig. 1, the head drive apparatus 10 comprises: a piezoelectric element 11 provided to correspond to each of plural nozzles of an inkjet printer; a head drive circuit 12 for supplying a drive signal to one-side electrode 11a of each piezoelectric element 11; a current amplifying circuit 13 and a switch circuit 14 that are provided between this head drive circuit 12 and each piezoelectric element 11; and a first capacitor 20 and a charge circuit 21 that apply a predetermined voltage to the other, ground-side electrode 11b of each piezoelectric element 11.

[0025]

Here, Fig. 1 shows only one piezoelectric element 11. However,

actually, a head of the inkjet printer is provided with plural nozzles and one piezoelectric element is provided to correspond to each nozzle. And, the drive signal COM from the head drive circuit 12 is sequentially outputted to each piezoelectric element 11, actually via a shift register or the like. The piezoelectric element 11, which is a piezo-element for example, is configured to be displaced by a voltage applied between both electrodes 11a and 11b.

[0026]

Then, the piezoelectric element 11 is always charged in the vicinity of an intermediate potential Vc. When discharged based on the drive signal from the head drive circuit 12, the piezoelectric element 11 is configured to pressurize ink in the corresponding nozzle to thereby eject an ink droplet through this nozzle. The head drive circuit 12, configured as a driver IC, generates the drive signal COM for the head of the inkjet printer and is disposed in a printer body for example.

[0027]

The current amplifying circuit 13 comprises two transistors: a first transistor 15 and a second transistor 16. The first transistor 15 has a collector connected to a constant voltage power supply, a base connected to the output of the head drive circuit 12, and an emitter connected to the input side of the switch circuit 14. Thereby, electrical conduction is established based on a signal from the head drive circuit 12, thus supplying a constant voltage to the piezoelectric element 11 via the switch circuit 14.

[0028]

Besides, the second transistor 16 has an emitter connected to the input side of the switch circuit 15, a base connected to the output of the head

drive circuit 12, and a collector connected to the charge circuit 21 as described later. Thereby, electrical conduction is established based on a signal from the head drive circuit 12, thus discharging the piezoelectric element 11 via the switch circuit 14, and the discharged electric charge is supplied to the charge circuit 21.

[0029]

Upon receipt of a control signal, the switch circuit 14 is turned on with the drive timing of the corresponding piezoelectric element 11, thus outputting the drive signal COM to the piezoelectric element 11. The first capacitor 20, in order to apply its charge voltage as a bias voltage Vb to the ground-side electrode 11b of each piezoelectric element 11, has one end connected to the ground-side common electrode 11b of the piezoelectric element 11, and the other end connected to ground.

[0030]

Additionally, the capacity of the first capacitor 20 is selected to be sufficiently greater than the total capacitance (about several μF) of all the electrostatic elements 11, for example, about several hundreds μF to 5600 μF, in order that a stable bias voltage can be supplied to each piezoelectric element 11.

[0031]

The aforesaid charge circuit 21 comprises a third transistor 22, a second capacitor 23, and a constant voltage circuit 30. The third transistor 22 has an emitter connected to the collector of the second transistor 16 of the aforesaid current amplifying circuit 13, a collector connected to ground, and a base connected to the head drive circuit 12 via a constant voltage diode 24.

[0032]

Thereby, as shown in dotted line in Fig. 2A, a voltage V3, lower than the voltage of the drive signal COM by a voltage applied by the constant voltage diode 24, is applied to the base of the third transistor 22. The third transistor 22 comes into conductive relationship with the drive signal COM only when the aforesaid voltage V3 is higher than the intermediate potential Vc.

[0033]

The aforesaid second capacitor 23 has one end connected to the emitter of the third transistor and the collector of the second transistor 16 of the current amplifying circuit 13, and the other end connected to ground. Additionally, the second capacitor 23 may be charged all the time or before print start, for example, with a constant voltage applied thereto via a high-resistance resistor. Besides, the second capacitor 23 may also be charged so that its voltage is gradually raised by not-shown means at the time of print start.

[0034]

The aforesaid constant voltage circuit 30 is a constant voltage circuit of well-known configuration in case of the illustration and comprises a fourth transistor 31, a constant voltage diode 32, and a resistor 33. The fourth transistor 31 has a collector connected to the one end of the second capacitor 23, an emitter connected to the one end of the first capacitor 20, and a base connected to the constant voltage diode 32. The constant voltage diode 32 has the other end connected to ground. The resistor 33 has one end connected to the one end of the second capacitor 23 and the other end connected to the base of the fourth transistor 31.

[0035]

The head drive apparatus 10 according to this embodiment is configured as aforesaid and operates as follows based on the head drive method according to the invention. The piezoelectric element 11 driven during printing will first be described. At the time of print start of the inkjet printer, as shown in Fig. 3A, a charge signal NCHG is inverted to an L level for a time period of 100 μs for example. Thereby, the potential of the drive signal COM from the head drive circuit 12 is raised to the intermediate potential Vc, as shown in Fig. 3A.

[0036]

Thereby, the drive signal COM causes a current to flow from the first transistor 15 of the current amplifying circuit 13 via the switch circuit 14 to the one-side electrode 11a of the piezoelectric element 11, thus charging the one-side electrode 11a of the piezoelectric element 11. Thereby, the potential of the one-side electrode 11a of the piezoelectric element 11 is raised to the intermediate potential Vc, as shown in solid line in Fig. 3B.

[0037]

At this time, the charge voltage of the first capacitor 20 is applied, as the bias voltage Vb, to the other, ground-side common electrode 11b of each piezoelectric element 11. Thereby, the potential of the other, ground-side common electrode 11b is held at the predetermined voltage Vb, as shown in dotted line in Fig. 3B.

[0038]

Here, the potential of the ground-side electrode 11b of the piezoelectric element 11 is held at the predetermined voltage Vb. Therefore,

the potential difference between both electrodes 11a and 11b of the piezoelectric element 11 is Vb at the time of print start. However, this potential difference Vb is lower than the intermediate potential Vc of the drive signal COM. Thus, the piezoelectric element 11 will not malfunction ejecting an ink droplet.

[0039]

Then, during printing, based on variation in the drive signal COM, when the potential of the drive signal COM is higher than the intermediate potential Vc, the one-side electrode 11a of the piezoelectric element 11 is charged via the first transistor 15 of the current amplifying current 13. Besides, when the potential of the drive signal COM is lower than the intermediate potential Vc, the one-side electrode 11a of the piezoelectric element 11 is discharged via the second transistor 16 of the current amplifying circuit 13. Thereby, the piezoelectric element 11 operates based on the drive signal COM, thus ejecting an ink droplet.

[0040]

Then, as shown in Fig. 2B, the discharged electric charge obtained by the aforesaid discharging is stored in the second capacitor 23 via the diode 25 of the charge circuit 21, thus charging the second capacitor 23.

[0041]

Here, as shown by reference character X in Fig. 3B, the voltage of the piezoelectric element 11 drops halfway due to self-discharge, so that the potential of the one-side electrode 11a becomes lower than the intermediate potential Vc. To prevent such a phenomenon, as shown by reference character Y in Fig. 3C, the charge signal NCHG generates L level pulses at regular

cycles of the drive signal COM, i.e., with a timing such that there appears no variation in the drive signal COM.

[0042]

Thereby, based on the drive signal COM from the head drive circuit 12, the one-side electrode 11a of the piezoelectric element 11 is charged via the first transistor 15 of the current amplifying circuit 13. Thus, the potential of the one-side electrode 11a of even the non-driven piezoelectric element 11 is held at the intermediate potential Vc.

[0043]

On the contrary, the first capacitor 20 applies the bias voltage Vb to the other, ground-side common electrode 11b of each piezoelectric element 11. Thereby, the potential of the other, ground-side common electrode 11b is held at this voltage. Accordingly, the potential difference between both electrodes 11a and 11b of each piezoelectric element 11 becomes (Vc-Vb).

[0044]

Additionally, if the charge voltage of the first capacitor 20 i.e. the bias voltage Vb is adjusted to become equal to the intermediate potential Vc, the potential difference between both electrodes 11a and 11b of each piezoelectric element 11 becomes zero. Furthermore, at the time of print end (END), as shown in Fig. 3A, the drive signal COM from the head drive circuit 12 is discharged from the one-side electrode 11a of the piezoelectric element 11 via the second transistor 16 of the current amplifying circuit 13. Thereby, the potential of the drive signal COM is lowered to a potential of zero.

[0045]

On the contrary, the one-side electrode 11a of the non-driven

piezoelectric element 11 is always charged to and held at the intermediate potential by the drive signal COM from the head drive circuit 12.

[0046]

Thus, the potential of the ground-side electrode 11b of each piezoelectric element 11 is held at the predetermined bias voltage Vb by the charge voltage of the first capacitor 20. Therefore, the potential difference between both electrodes 11a and 11b of the piezoelectric element 11 is held small. At the same time, when the driven piezoelectric element and the non-driven piezoelectric element are adjacent to each other, the potential difference between the one-side electrodes 11a of these piezoelectric elements is also held small. Accordingly, power consumption of the piezoelectric element 11 is reduced, and the voltage drop due to self-discharge of the piezoelectric element 11 is small, thus reducing a power loss.

[0047]

Besides, the potential difference between the driven piezoelectric element 11 and the non-driven piezoelectric element 11 becomes small. Therefore, even when such piezoelectric elements are adjacent to each other, the occurrence of discharge between the piezoelectric elements 11 is reduced. At the same time, even when the withstanding pressure of the individual piezoelectric elements 11 is reduced due to an increase in density, there is no need to perform insulating between the piezoelectric elements 11. Therefore, the increase in density of the head can be easily realized.

[0048]

Furthermore, the first capacitor 20 and the second capacitor 23 of the charge circuit 21 are charged utilizing the discharged electric charge obtained

by the discharging of each piezoelectric element 11. Therefore, there is no particular need of a power supply circuit for generating the bias voltage Vb.

[0049]

In the aforesaid embodiment, the piezoelectric element 11 uses a piezo-element for example but is not limited thereto. Alternatively, another piezoelectric element such for example as an electrostriction element or a magneto-striction element may be used.

[0050]

Besides, the aforesaid embodiment illustrates the constant voltage circuit 30 configured to utilize the constant voltage diode 32. However, the constant voltage circuit 30 is not limited thereto. For example, as shown in Fig. 4, the constant voltage circuit 30 can utilize a constant voltage circuit configured to utilize resistors R1 and R2. Otherwise, as shown in Fig. 5, the constant voltage circuit 30 can utilize constant voltage circuits of various well-known configurations such as utilizing resistors R1, R2, R3 and a reference power supply P.

[0051]

[Advantage of the Invention]

As described above, according to the invention, based on the charge voltage of the first capacitor charged by the charge circuit utilizing the discharged electric charge of the piezoelectric element, the bias voltage is applied to the ground-side electrode of the piezoelectric element. Thereby, the ground-side electrode of the piezoelectric element is held at the bias voltage. This bias voltage utilizes electric charge discarded from the head, thus creating an alternative power supply. Thus, power consumption is reduced,

and the voltage drop due to self-discharge of the piezoelectric element is small, so that a high-precision waveform is reproduced.

[Brief Description of the Drawings]

[Fig. 1]

A block diagram showing the configuration of an embodiment of a head drive apparatus according to the invention;

[Fig. 2]

A timing diagram showing variations in (A) the base voltage of a third capacitor of a charge circuit and (B) the current of a diode, in the head drive apparatus of Fig. 1;

[Fig. 3]

A timing diagram showing variations in (A) a drive signal, (B) the voltages of both electrodes of a piezoelectric element, and (C) a charge signal, in the head drive apparatus of Fig. 1;

[Fig. 4]

A partial circuit diagram showing another configuration example of a constant voltage circuit of the charge circuit in the head drive apparatus of Fig. 1; and

[Fig. 5]

A partial circuit diagram showing still another configuration example of the constant voltage circuit of the charge circuit in the head drive apparatus of Fig. 1.

[Description of the Reference Numerals and Signs]

10: Head drive apparatus

11: Piezoelectric element

11a: One-side electrode

11b: Ground-side electrode

12: Head drive circuit

13: Current amplifying circuit

14: Switch circuit

15: First transistor

16: Second transistor

20: First capacitor

21: Charge circuit

22: Third transistor

23: Second capacitor

24: Constant voltage diode

25: Diode

30: Constant voltage circuit

31: Fourth transistor

32: Constant voltage diode

33: Resistor

[Designation of Document] ABSTRACT

[Abstract]

[Problem] An object of the invention is to provide a head drive apparatus and method, for an inkjet printer, configured such that a voltage applied between electrodes of each piezoelectric element is reduced with a simple configuration.

[Means for Resolution] In a head drive apparatus 10, for an inkjet printer, in which a piezoelectric element 11 provided to correspond to each of plural nozzles is selectively driven with a predetermined print timing by a drive signal COM from a head drive circuit 12, thus ejecting an ink droplet through the corresponding nozzle to perform printing, the head drive apparatus 10 is configured to comprise a first capacitor 20 for applying a predetermined bias voltage to a ground-side electrode 11b of each piezoelectric element and a charge circuit 21 for charging the aforesaid first capacitor utilizing electric charge obtained by discharging each piezoelectric element.

[Selected Drawing] Fig. 1

Fig. 1

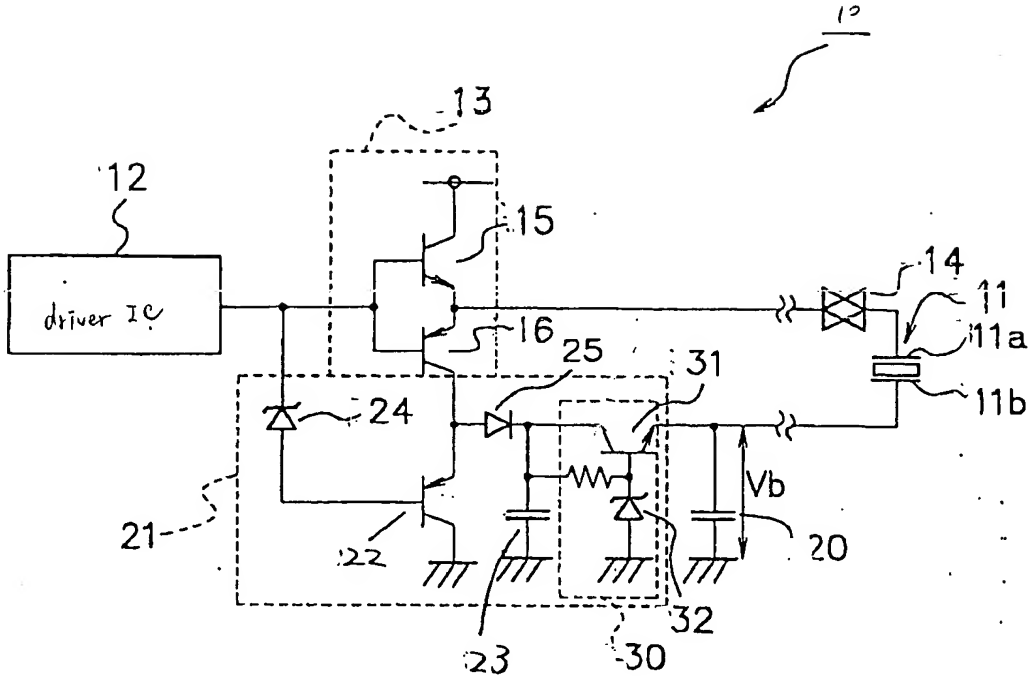

10
13
12
driver IC
15
14
11
11a
16
25
31
11b
24
Vb
21
22
20
32
23
30

Fig. 2

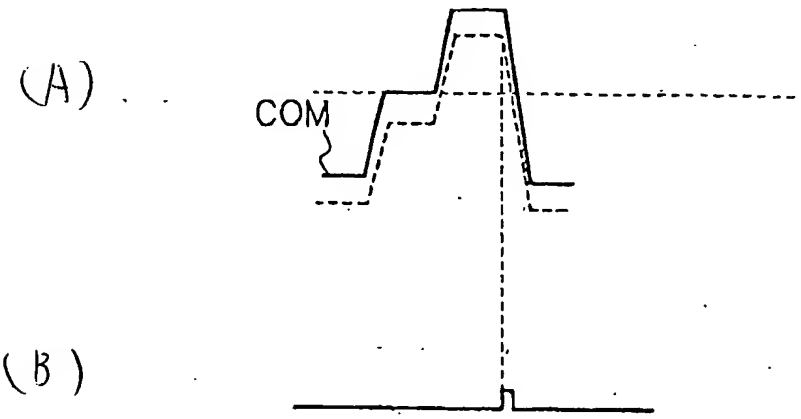

(A)
COM
(B)

Fig.3

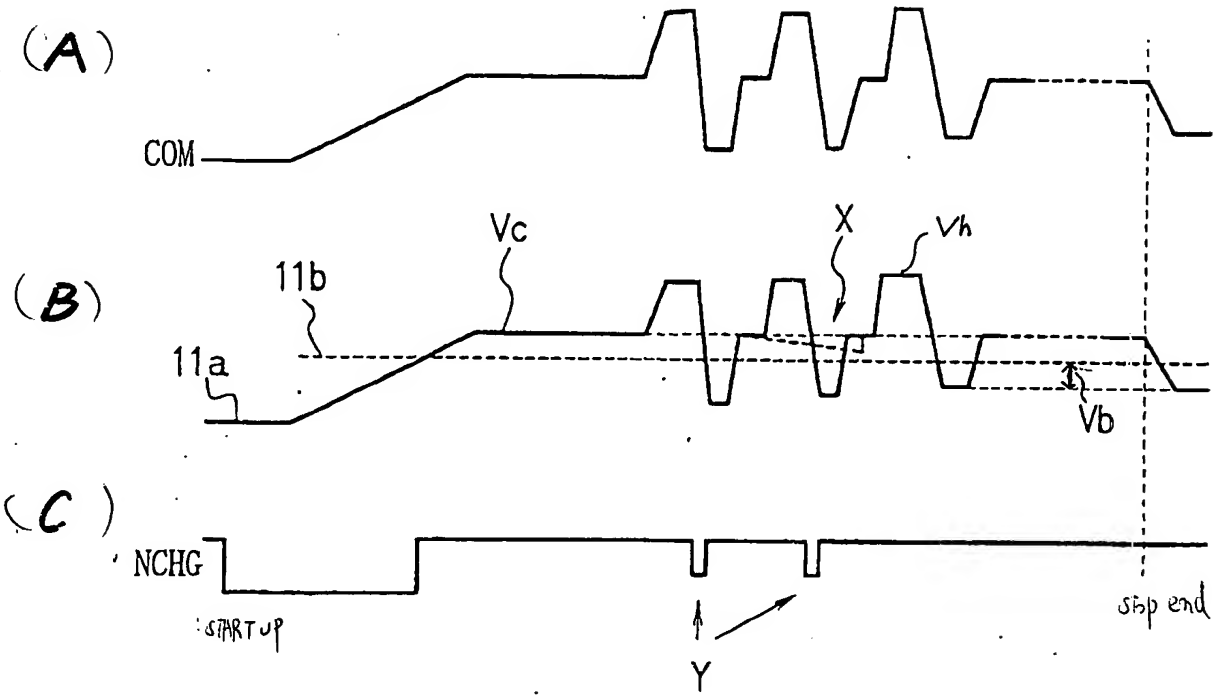


Fig. 4

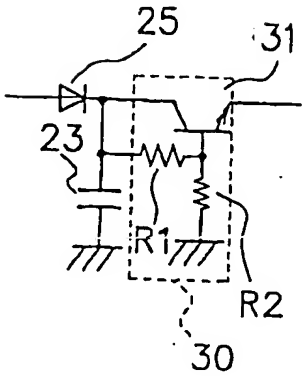
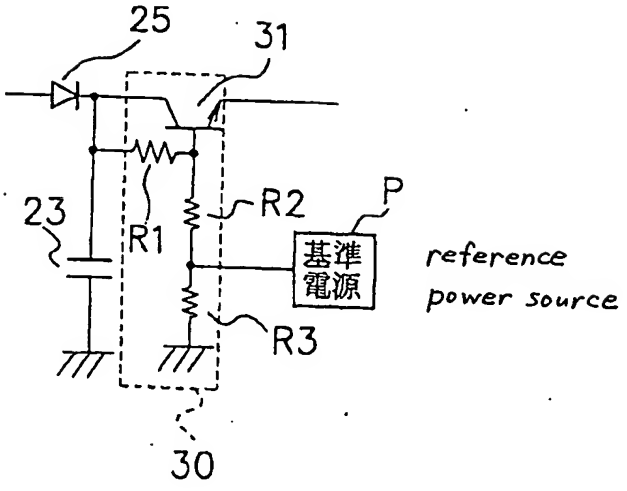

25
31
23
R1
R2
30

Fig. 5


25
31
23
R1
R2
P
基準
電源
reference
power source
R3
30